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Is there a Matthew effect in self-regulated learning and mathematical strategy application? - Assessing the effects of a training program with standardized learning diaries

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ABSTRACT

The aim of this study was to examine the differential effects of a training program on low- and high-achievers' self-regulatory and mathematical problem-solving competencies. The training concept is based on a process model of self-regulation, which differentiates between three phases in each learning process: pre-action, action, and post-action phase. In total, 89 fourth grade students voluntarily participated in the training program. Based on their math grade the students were grouped into low-achievers ($N = 34$) and high-achievers ($N = 55$). The training was evaluated by a learning diary, which students filled out every day right before and after learning. The process data gained was analyzed with interrupted time series analyses as well as trend analyses. The results of these analyses revealed that low- and high-achievers show different patterns in their effects. Altogether, high-achievers seemed to benefit more from the training program. The results are discussed in detail concerning their theoretical and practical implications.

1. Introduction

Many empirical studies stress the importance of combining the instruction of subject-specific strategies with the training of interdisciplinary skills. Brown, Bransford, Ferrara, and Campione stated as early as 1983 that the mere training of subject-specific strategies assures neither their long-term application nor their transfer to other tasks. Hasselhorn and Hager (2001) concluded by demanding the implementation of interdisciplinary strategies like self-monitoring, self-control, and self-regulation into subject-specific training, which should function as a "transfer vehicle" and lead to more sustained effects. The advantage of combined training over mere subject-specific instruction was demonstrated in several studies (e.g., Perels, Gürtler, & Schmitz, 2005; Souvignier & Mokhlesgerami, 2006). Moreover, combined training programs seem to be particularly effective when self-regulated learning is combined with mathematics (Dignath, Büttner, & Langfeldt, 2008). Thus, the present paper evaluates a combined training program which aims to promote students' self-regulated learning as well as their application of mathematical problem-solving strategies.

However, the aim of the present study was to go beyond examining the training effects by investigating the differential effects which the training had on low- and high-achieving students. Such differential training effects based on students' performance are still controversial. On the one hand, some researchers assume a *Matthew effect* (see also Bodovski & Farkas, 2007; Morgan, Farkas, & Hibel, 2008; Morgan, Farkas, & Wu, 2011), which refers to the bible verse in the Gospel of Matthew 13:12 "Whoever has will be given more, and they will have abundance. Whoever does not have, even what they have will be taken from them." In the educational context this means that the subsequent academic progress is triggered by the initial success or failure of a student, which in turn leads to a widening of differences and inequalities (Scarborough & Parker, 2003). If initial advantage tends to beget further advantage it could be suggested that high-achieving students tend to benefit more from subject-specific training programs than their low-achieving classmates. At the same time, high-achieving students are presumed to show high self-regulated learning behavior and thus can already effectively apply problem-solving strategies, which finally leads to high performance. Thus, if high mathematical achievement is usually due to an advantage in self-regulatory strategies then conducting a training on such strategies could be hypothesized to affect low-achievers to a much higher extent because they start out lacking

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more in these competencies (see also De Corte, Mason, Depaepe, & Verschaffel, 2011). Investigating which one of these two assumptions can be supported by empirical findings has also practical implications: Following the Matthew effect low-achieving students should get a separate additional intervention to boost their learning and performance, whereas the second approach indicates a classwise common training as all students could benefit depending on their specific needs. However, studies are inconsistent concerning the effects of trainings on self-regulated learning, either indicating that high-achievers benefit most from such training (Sontag & Stoeger, 2015) or finding no differential effects for specific subgroups (Stoeger & Ziegler, 2010).

The evaluation of such training programs is usually carried out by comparing pre-test and post-test measures, an approach that involves some advantages (e.g., low expense). However, this method of measuring change over time holds some methodical problems. Given the assumptions of the classical test theory, a pre-post comparison is highly prone to measurement errors, especially for state variables, which can change day to day (see Schmitz & Wiese, 2006). Thus, interventions which aim at changing behavior should be evaluated by measurements that are more sensitive to changes and are able to record the everyday development of one or more target variable(s) (Schmitz, Klug, & Schmidt, 2011). One possibility for collecting such process data on academic learning is the use of learning diaries, which have to be filled out by the participants every day. In the context of self-regulated learning such diaries have been proven to be an effective means for assessing the use of learning strategies (e.g., Costa Ferreira, Veiga Simão, & Lopes da Silva, 2015; Glogger, Schwonke, Holzäpfel, Nückles, & Renkl, 2012). This daily recording of the target variables allows both the documentation of student development and the identification of the effect of single training sessions on the target variable(s). In order to meet these demands, the student training in the present study was evaluated by means of a learning diary, which was analyzed by time series analyses. Thus, we investigated how single training sessions as well as the overall intervention affect the self-regulated learning behavior and mathematical problem-solving behavior of German low-achieving and high-achieving fourth graders.

1.1. Self-regulated learning and mathematical problem-solving

According to Pintrich (2000, p. 453), self-regulated learning is "… an active, constructive process whereby learners set goals for their learning and then attempt to monitor, regulate, and control their cognition, motivation, and behavior, guided and constrained by their goals and the contextual features in the environment." This definition shows that self-regulated learning is not a simple construct. It consists rather of several components interacting in order to afford effective learning. As the present paper focuses on possibilities to improve students' self-regulated learning and mathematical problem-solving, the latter term also needs to be defined. In our study we refer to mathematical problem-solving as a usage of mathematical methods and strategies in order to find solutions to word problems. In mathematics education, such word problems are used to connect real-world situations to the abstract language of mathematics. According to Marcou and Philippou (2005), particularly for primary students mathematical problem-solving can be considered to be one of the most difficult tasks, as it requires the application of multiple skills. Among other domain-specific knowledge and strategies, also metacognitive skills are needed in order to decide about when and what resource and strategy to use. This means mathematical problem-solving requires a high level of self-regulation when adequately applying mathematical strategies (De Corte et al., 2011). Students with difficulties in mathematics seem to possess only low metacognitive and self-regulatory competencies (Geary, 2003; Wong, Graham, Hoskyn, & Berman, 2008). This goes in line with the empirical findings of numerous studies which reveal a strong relationship between self-regulated learning and academic achievement (e.g., Buric & Soric, 2012; Friedrich, Jonkmann, Nagengast, Schmitz, & Trautwein, 2013; Fuchs et al., 2003; Krebs & Roebers, 2012; Purdie & Hattie, 1996; Rosário, Núñez, Valle, González-Pienda, & Lourenco, 2013; Villavicencio & Bernardo, 2013). That is, high-achieving students can be characterized as highly self-regulated learners, indicating that the use of self-regulatory strategies goes along with better performance. Indeed, self-regulated learning has even been found to be predictive for academic performance (e.g., Cleary & Callan, 2014; Helle, Laakkonen, Tuijula, & Vermunt, 2013; Nota, Soresi, & Zimmerman, 2004). Thus, fostering self-regulated learning seems to be a promising approach especially for those students who are struggling with learning in mathematics in order to optimize their educational trajectories.

1.2. Theoretical training model

Intervention studies in the educational context usually base on a model, which theoretically summarizes how students' learning can be fostered. In the present study, the conceptual design of the student training relates to the model of self-regulation by Schmitz and Wiese (2006); Fig. 1), which is largely based on Zimmerman's (2000) model. This model can be classified as a process model of self-regulation (see Winne & Perry, 2000). In contrast to component models of self-regulation (e.g., Boekaerts, 1999), which outline relatively stable advantageous competencies of self-regulated learners, process models describe an ideal learning process with distinguishable phases (Wirth & Leutner, 2008).

In line with Zimmerman's (2000) model, self-regulated learning is assumed to consist of three consecutive phases. According to Schmitz and Wiese (2006), these three phases are named pre-action (before learning), action (during learning), and post-action (after learning). The *pre-action phase* focuses on the preparation of the students' learning. Depending on the situational conditions and the given task, the learners set a goal which is supposed to be realistic and challenging (see Locke & Latham, 2002). As goal-setting is always motivating, it marks the start of planning the learning process (Otto, 2010). By planning the learning process the learners have to think of potential (subject-specific) learning strategies, which they could apply in order to solve the task successfully (planning the strategy), as well as how long they will need for solving the task (planning the time). Furthermore, the initial motivation and affect is crucial in the pre-action phase. The learning process depends on the learners' self-efficacy, their intrinsic motivation as well as on their learning related emotions. High self-efficacy occurs when students expect to be able to solve a difficult task successfully (Bandura, 1997). At the same time, highly intrinsically motivated students learn because they perceive the task as being interesting or challenging, which also depends on their feeling of being competent (Niemiec & Ryan, 2009). Thus, whenever the students are faced with an interesting task (high intrinsic motivation), which they expect to be solvable for them (high self-efficacy), this results in high motivation to begin with learning. In contrast, if they perceive the task as uninteresting (low intrinsic motivation) and/or are convinced that they will not be able to succeed (low self-efficacy), the chance is high that the students will procrastinate. In this case, they can apply self-motivating strategies in order to facilitate the beginning of learning. Associated with students' motivational variables, different learning related emotions can be distinguished (see Pekrun, Goetz, Titz, & Perry, 2002). When a student feels competent for solving a given task, positive emotions like enjoyment are more likely to occur, which in turn foster self-regulated learning (Pekrun, 2006). On the other hand, being faced with a very difficult task leads to experiencing negative emotions such as anxiety and hopelessness (Goetz, Nett, & Hall, 2013).

With these given external and internal preconditions, the learning starts (*action phase*) and students apply different learning strategies to solve the task. Given that highly self-regulated learners have a wide repertoire of learning strategies, they are expected to show better cognitive processing (de Bilde, Vansteenkiste, & Lens, 2011). However, low-achieving students have been found to apply fewer and less effective